CLAIMS

1. A spindle for a grinding wheel which is to grind re-entrant cams on camshafts comprising a drive motor, a shaft extending from the motor at the end of which is mounted a grinding wheel, and a rigid elongate casing extending from the motor and encasing the shaft, wherein the length of the shaft and casing is selected to be at least as long as the axial length of cam shafts to be ground by the wheel, the shaft is carried in three bearings each of which is a hydrostatic bearing, and one of the bearings is located near the end of the shaft carrying the grinding wheel so as to be at the end of the rigid casing remote from the motor, thereby to increase the shaft stiffness and increase its resistance to bending.

2. A spindle as claimed in claim 1 wherein a second bearing is located at the inboard end of the external part of the shaft, and the third bearing is located within the motor at the said other end of the shaft.

3. A spindle as claimed in claim 1 or 2 wherein the shaft is constructed so as to have at least two different diameters, and that part of the shaft which extends within the motor has a greater diameter than does that part of the shaft which extends axially externally therefrom.

4. A spindle as claimed in any of claims 1 to 3 wherein the grinding wheel, is demountably fixed to the shaft.

5. A spindle as claimed in any of claims 1 to 4 wherein the motor is an electric motor.

6. A spindle as claimed in claim 5 wherein the stator of the motor is secured within a rigid housing and the non-rotating element of each of the three bearings is secured within either the rigid elongate casing or the rigid motor housing.

7. A spindle as claimed in claim 5 or 6 wherein the axial length of the rotor-bearing part of the shaft is shorter than the external part of the shaft, and the shaft is constructed so that the stiffness and the support of the shorter part of the shaft situated between the second and third bearings dictate that the bending resonance of the longer external part is above the critical spindle rotational frequency

8. A spindle as claimed in any of claims 5 to 7 in which a symmetrical design of housing is employed for the motor.

9. A spindle as claimed in claim 8 wherein the motor housing includes a water cooling jacket in which water is forced to follow a helical path around the motor, so as to avoid cooling one side of the motor more than another,

10. A spindle as claimed in any of claims 1 to 9 wherein the spindle is constructed to be axisymmetrical, so that any heat generated within the bearings dissipates radially into the surrounding material in a uniform manner, so that in use the spindle housing will tend to warm up and cool down uniformly, and therefore expand and contract uniformly.

11. A spindle as claimed in any of claims 1 to 10 in which, in use, oil is supplied under pressure to the bearings by a pump which draws oil from a reservoir to which oil returns from the bearings.

12. A spindle as claimed in claim 11 wherein the oil is heated in each bearing and the heated oil drains into lower regions of the enclosure formed by the rigid elongate shaft casing and the motor housing, and the lower regions of the enclosure thereby can become heated in use to a higher temperature then the upper regions thereof

13. A spindle as claimed in claim 12 wherein the lower regions of the enclosure are formed as a separate oil collection box which is mounted to the remainder of the enclosure in such a manner that it will not impart a strain on the spindle shaft.

14. A spindle as claimed in claim 12 and 13 wherein a thermal barrier is provided between the said lower regions and the remainder of the enclosure to reduce the transfer of heat from the hot oil to the upper regions of the enclosure and thereby prevent thermally induced misalignment of the three bearings and any strain on the spindle shaft caused by any such misalignment.

15. A method of constructing a spindle as claimed in claim 1 wherein during assembly the internal bores of two of the bearings are initially aligned and the third bearing is adjusted radially to bring all three bores into alignment.

16. A spindle constructed arranged and adapted to operate as described therein and with reference to the accompanying drawings.

AMENDED CLAIMS

[received by the International Bureau on 11 August 2005 (11.08.05);
original claims 1-16 replaced by new claims 1-12 (3 pages)]

1. A spindle for a grinding wheel which is to grind re-entrant cams on camshafts comprising a shaft at one end of which is mounted the grinding wheel, drive means for driving the other end of the shaft, and a rigid elongate casing extending axially from the drive means and encasing the shaft, characterised in that the drive means is an electric motor, and in that the length of the shaft and casing is selected to be at least as long as the axial length of a camshaft to be ground by the wheel, the shaft being carried in three hydrostatic bearings, one of which is located near said one end of the shaft so as to be at the end of the rigid casing remote from the motor, thereby to increase the shaft stiffness and increase its resistance to bending, the two other bearings disposed on opposite sides of the motor.

2. A spindle as claimed in claim 1 wherein the second bearing is located at the inboard end of the external part of the shaft, and the third bearing is located within the motor at said other end of the shaft.

3. A spindle as claimed in claim 1 or claim 2 wherein the stator of the motor is secured within a rigid housing and the non-rotating element of each of the three bearings is secured within either the rigid elongate casing or the rigid motor housing.

4. A spindle as claimed in claim 2 or claim 3 wherein the axial length of the part of the shaft which carries the rotor of the motor is shorter than the external part of the shaft, the shaft being constructed so that the stiffness and the support of the shorter part of the shaft situated between the second and third bearings dictate that the bending resonance of the longer external part is above the critical spindle rotational frequency.

5. A spindle as claimed in any one of claims 1 to 4 in which a symmetrical design of housing is employed for the motor.

6. A spindle as claimed in claim 5 wherein the motor housing includes a water cooling jacket in which water is forced to follow a helical path around the motor, so as to avoid cooling one side of the motor more than another.

7. A spindle as claimed in any one of claims 1 to 6 wherein the spindle is constructed to be axisymmetrical, so that any heat generated within the bearings dissipates radially into the surrounding material in a uniform manner, so that in use the spindle casing will tend to warm up and cool down uniformly, and therefore expand and contract uniformly.

8. A spindle as claimed in any one of claims 1 to 7 in which, in use, oil is supplied under pressure to the bearings by a pump which draws oil from a reservoir to which oil returns from the bearings.

9. A spindle as claimed in claim 8 comprising an enclosure formed by the rigid casing and a housing for the motor, wherein oil heated in use in each bearing drains into the lower regions of the enclosure and can thereby become heated to a higher temperature then the upper regions thereof.

10. A spindle as claimed in claim 9 wherein the lower regions of the enclosure are formed as a separate oil collection box which is mounted to the remainder of the enclosure in such a manner that it will not impart a strain on the spindle shaft.

11. A spindle as claimed in claim 9 or claim 10 wherein a thermal barrier is provided between the said lower regions and the remainder of the enclosure to reduce the transfer of heat from the hot oil to the upper regions of the enclosure and thereby prevent thermally induced misalignment of the three bearings and any strain on the spindle shaft caused by any such misalignment.

12. A method of constructing a spindle as claimed in claim 2 wherein during assembly the internal bores of two of the bearings are initially aligned and the third bearing is adjusted radially to bring all three bores into alignment.

Statement under Art.19 (1)

In response to the International Search Report and the Written Opinion dated 27th April 2005, we are concurrently filing an amended set of claims in the above Application.

The Written Opinion considers that present claims 1-4 and 10-13 lack novelty in view of cited document D1 (DE19635687), and that claims 5-9 and 14 lack novelty and/or inventive step in view of documents D1-D3.

Document D1 discloses a device for grinding camshafts, in which the cams have concave re-entrant flanks of small diameter, requiring grinding wheels of correspondingly small diameter. In accordance with the described embodiments, this is achieved by having a spindle shaft (1) driven by a belt drive (11) and supported by a pair of hydrostatic bearings (16). Axial thrust is taken up either by a hydrodynamic bearing (24, 26) or by a pair of roller bearings (28) – see Figure 3. This arrangement which is axially relatively short, enables the device to be moved axially along the length of a camshaft and to radially engage a cam without fouling other cams positioned therebelow.

However, a significant inherent disadvantage of the arrangement of D1 resides in the belt drive *per se*. Thus it is generally considered in the relevant industry that belt drives should preferably be avoided, for the following reasons: they are limited in power transmission at speed; are generally complicated in terms of belt tensioners, guards, etc.; are less reliable since they are prone to belt breakage; and they apply a substantial radial force upon the driven shaft, requiring more robust bearings to take up such loading.

The philosophy behind the present invention is quite different. Amended claim 1, which has now been drafted in two part form, with the pre-characterising part being based on D1, now specifies *inter alia* an electric motor drive, with the length of the driven shaft and casing being at least as long as the length of a camshaft to be ground. The claim also distinguishes over D1 in providing three hydrostatic bearings, two of which are disposed on opposite sides of the electric motor, ensuring a wear-free arrangement, with the robust, high-stiffness attributes associated with hydrostatic bearings. The

additional features of new claim 4 advantageously avoid spindle resonance, due to the overhung mass of the electric motor.

In summary, we submit that claim 1 and its dependant claims clearly distinguish over document D1, so that all the present claims should be found to be allowable.

Yours faithfully,
KEITH W NASH & CO